Megalagrion xanthomelas

Orangeblack Hawaiian damselfly

Species Report

Version 1.0

Photo description: *Megalagrion xanthomelas* (male) from Kapuāiwa Coconut Grove near Kaunakakai, Molokaʻi; Photo credit: Dr. William Haines, DOFAW

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EXECUTIVE SUMMARY

This Species Report for the orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*, was completed to assess the species' biology, threats and conservation actions, and current status. The U.S. Fish and Wildlife Service (Service) identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and identified the factors influencing the species current condition. We used the conservation biology principles of resiliency, redundancy, and representation to assess the overall viability for *M. xanthomelas*.

Megalagrion xanthomelas is an endangered endemic species historically found on all of the Hawaiian islands, except Kahoʻolawe, at elevations ranging from 0 to 200 feet (61 meters). This species is now believed to be limited to thirty-four populations: 1 on Oʻahu, 3 on Maui, 7 on Molokaʻi, and 23 on Hawaiʻi. The orangeblack Hawaiian damselfly inhabits streams, wetlands, and anchialine pools. Adult *M. xanthomelas* are considered weak flyers and do not stray far from the vicinity of breeding pools.

One of the greatest threats to *Megalagrion xanthomelas* includes habitat quality and availability. It is estimated that 12 percent of lowland to upper-elevation wetlands, 90 percent of anchialine pools, and one-fifth of stream habitats have since been lost. Other threats include nonnative plants and animals and a lack of population representation, resiliency, and redundancy due to its apparent low population sizes. Currently, existing regulations are inadequate to protect this species from introduction of nonnative species and to maintain quality habitat.

For the purpose of this Species Report, viability is the ability of *Megalagrion xanthomelas* to persist over time and avoid extirpation. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to adapt and persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events.

Resiliency of *Megalagrion xanthomelas* is considered low to moderate because there are multiple populations across four islands, but there is still a high risk of local extirpation from habitat destruction and non-native species. Although there are multiple populations, a number of them are clustered in specific geographic areas, which make them vulnerable to catastrophic events. In addition, because of habitat fragmentation, re-population from other scattered isolated populations are unlikely. Therefore, *M. xanthomelas* is also considered to have moderate redundancy. Representation is considered low to moderate for this species since low population numbers and reduced genetic diversity have been observed in populations of *M. xanthomelas*. Because of these parameters, inbreeding depression and other problems associated with small population size are likely already occurring. However, current conservation efforts including captive rearing and translocations provide an encouraging pathway for recovery. Therefore, the current viability of the orangeblack Hawaiian damselfly, *M. xanthomelas*, is low to moderate.

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INTRODUCTION

The orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*, is a member of the order Odonata and is endemic to the Hawaiian Islands. These damselflies can be found in streams, wetland areas, and anchialine pools. *Megalagrion xanthomelas* is only known from thirty-four sites across O‘ahu, Maui, Moloka‘i, and Hawai‘i island. Habitat degradation and loss, and predation and competition by invasive plants and animals are just a couple of the major threats that have limited the population of *M. xanthomelas*.

Species Report Overview

This biological report summarizes the biology and current status of *Megalagrion xanthomelas* and was conducted by the Pacific Islands Fish and Wildlife Office. The biological report provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service's Endangered Species Program. As such, the Species Report will be a living document upon which other documents such as recovery plans and 5-year reviews will be based.

Regulatory History

Megalagrion xanthomelas was listed as endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended (ESA) on September 30, 2016 (USFWS 2016 (81 FR 67786-67860)). All federal regulatory information can be found at the following link: https://ecos.fws.gov/ecp0/profile/speciesProfile?sId=6224.

A draft recovery plan that includes *Megalagrion xanthomelas* management on the island of Kaua‘i is available at https://ecos.fws.gov/docs/recovery_plan/Draft_KIRP_Hyperlinks_20200424.pdf.

A recovery outline for Hawaiian Multi-Island Species, which includes *Megalagrion xanthomelas*, was approved on August 2020 and is available at https://ecos.fws.gov/docs/recovery_plan/SIGNED_Multi-Island_recovery_outline_07-30-2020_1.pdf.

No critical habitat has been designated for *Megalagrion xanthomelas*.

Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government, academic, business, and industry reports), and expert elicitation.

Where little information was available for *Megalagrion xanthomelas*, we used information collected from other damselfly species in Hawai‘i to fill in these data gaps.

To assess the current status and viability of *Megalagrion xanthomelas*, we identified population units. These units were necessary in order to avoid confusion over any assumptions regarding the health of a group of individuals simply by calling it a population, as well as recognizing the lack of information available on the species to apply a classic definition of a population, such as a self-reproducing group of conspecific individuals that occupies a definite area over a span of evolutionary time, possesses an assemblage of genes (the gene pool) of its own, and has its own ecological niche. We define *M. xanthomelas* populations based on their geographical distance from one another on an island.

Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 500-meter buffer around each individual species point and polygon to include all points representing the same population. We then dissolved all buffer areas intersecting each other into a single shape. Finally, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

This Species Report assesses the ability of *Megalagrion xanthomelas* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, i.e., likelihood of avoiding extinction. To assess the viability of *M. xanthomelas*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs” (Figure 1; USFWS 2016, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

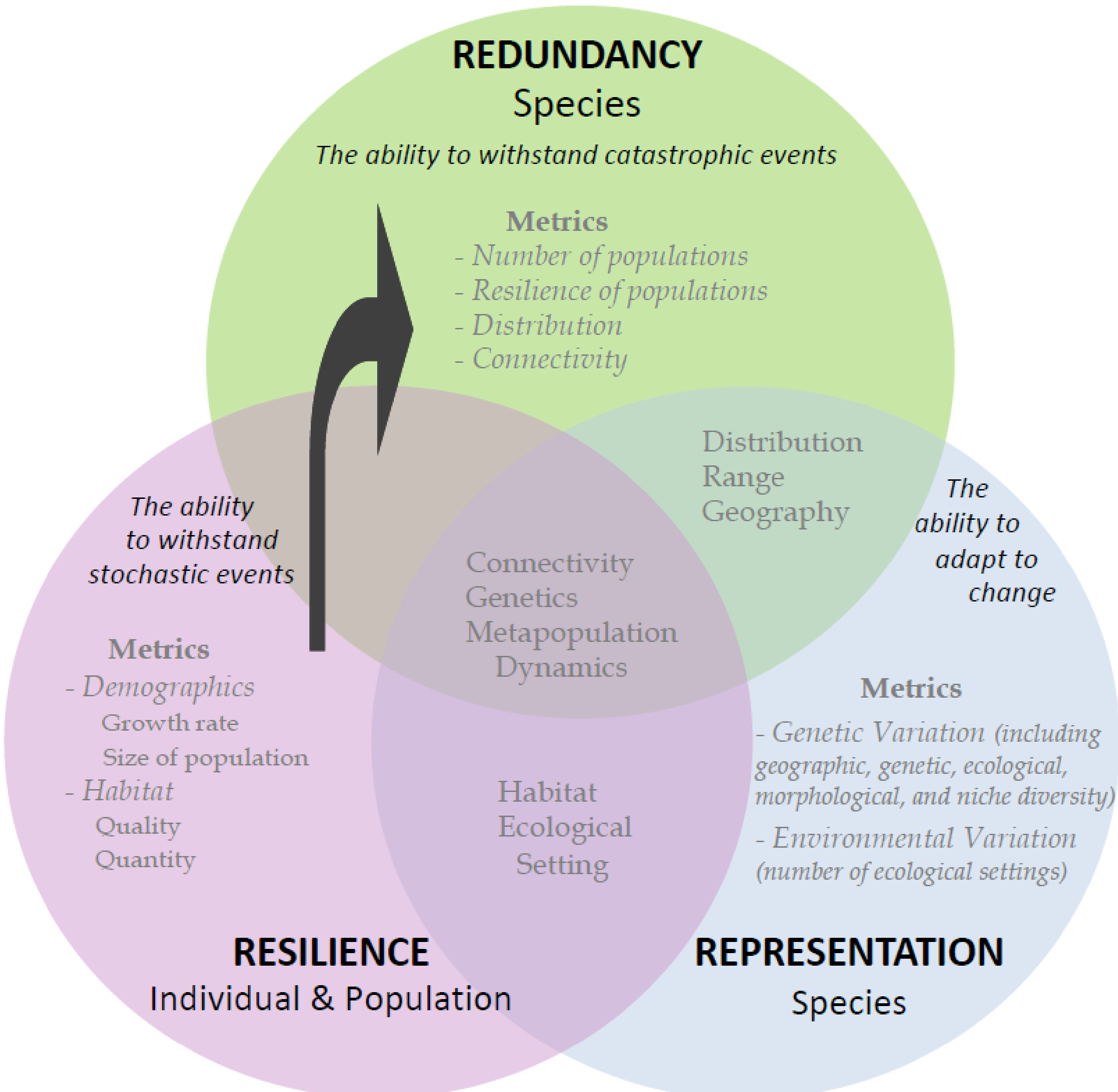


Figure 1. The three conservation biology principles of resiliency, redundancy, and representation (3Rs) used to assess species viability.

Definitions

Resiliency

Resiliency is the capacity of a population or a species to withstand the extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, a population or species found within a known area over for an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may be influenced by the connectivity among populations.

Redundancy

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Species redundancy is conferred when the geographic range of the species exceeds the impact area of a catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

Species Viability

Species viability is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. The 3Rs share ecological factors such as connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also provides access to the full range of habitats normally used by the species and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the individual and population level; redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number, and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Megalagrion xanthomelas.*

SPECIES ECOLOGY

Species Description

The orangeblack Hawaiian damselfly, *Megalarion xanthomelas* (Selys-Longchamps 1876, p.490–519), or pinapinao maʻalaea (Ulukau, 2020) is a damselfly species that is endemic to the Hawaiian Islands. This species is part of the order Odonata, which includes dragonflies and damselflies. It is estimated that the genus *Megalagrion* began its evolution as long as 10 million years ago (Jordan et al. 2003, p. 89). *Megalagrion* appears to be most closely related to species of *Pseudagrion* elsewhere in the Indo-Pacific (Zimmerman 1948, pp. 341, 345). The species *M. xanthomelas* was first described by McLachlan (1883, p. 234–235) from specimens collected by R.C.L. Perkins (1899) from streams on Lānaʻi and Maui.

The currently accepted taxonomy for this species is (ITIS 2020):
Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta
Order: Odonata
Family: Coenagrionidae
Genus: *Megalagrion*
Species: *xanthomelas*

Megalagrion xanthomelas adults are small to medium sized and measure from 1.3 to 1.5 inches (in; 33 to 37 millimeters; mm) in length and have a wingspan of 1.4 to 1.6 inches (35 to 40 mm). The males have a broadly striped red and black thorax with a predominantly black abdomen (Polhemus and Asquith 1996, p. 91). The female is similar to the male in its general color pattern, but instead of red markings, females have a tan coloration with their abdomen more heavily marked with black dorsally (Polhemus and Asquith 1996, p. 91).

The general biology of all Hawaiian damselflies of the genus *Megalagrion* is typical of other narrow-winged damselflies (Polhemus and Asquith 1996, pp. 2–7). *Megalagrion xanthomelas* adults, like most damselflies, are weak fliers (slow over short distances) and stay low amid the vegetation where they spend considerable time perching on vegetation and boulders (HCWCS 2005, p.1). When disturbed, the adults fly downward within nearby vegetation or between rocks, rather than up and away as is usually observed with aquatic Hawaiian damselfly species. The adults of many of the Hawaiian *Megalagrion* spp. are unusual in that they have a highly developed behavior of feigning death when caught or attacked (Polhemus and Asquith 1996, p. 7). This is likely a defensive behavior since adult damselflies are preyed upon by other damselflies, dragonflies, yellowjacket wasps, birds, and spiders (Polhemus and Asquith 1996, p. 7). Single females also tend to be found at greater distances from the water than single males and only go to the water to mate and lay eggs (Preston 2007, p. 272). In captivity, the average maximum adult lifespan is 57 days (Johnson 2001, p. 27).

Individual Needs
Habitat
The orangeblack Hawaiian damselfly is a lowland species that occupies a wide range of habitats (e.g. anchialine pools, coastal, and wetland ecosystems) and has broad ecological tolerances (Polhemus and Asquith 1996, p. 91). However, *Megalagrion xanthomelas* is most commonly found sheltering in the vegetation along the borders of low elevation streams and coastal wetlands, particularly those fed by basal springs (Polhemus and Asquith 1996, p. 91). They can also be found breeding along terminal and lower midreaches of perennial streams. If fish and other aquatic predators are not present, *M. xanthomelas* can also breed in reservoirs and ornamental ponds, as documented at the old Lodge at Kōʻele (now Four Seasons Hotel Lānaʻi at Kōʻele) on Lānaʻi (Polhemus and Asquith 1996, p. 91). This species can also exploit temporary habitats, such as ephemeral side pools bordering flashy streams on the island of Hawaiʻi and pipeline seepages on Lānaʻi (Polhemus and Asquith 1996, p. 91).

Megalagrion xanthomelas is typically observed at lower elevations (between 0–200 feet [61 meters]) but has been spotted up to 2,000 ft (610 m) (Polhemus and Asquith 1996, p. 92). Results from salinity readings at Palaʻau, Molokaʻi demonstrate that individuals there could tolerate concentrations of at least 2 ppt, and may be able to tolerate salinity as high as 8 ppt (Polhemus and Asquith 1996, p. 92).

Anchialine pools provide breeding habitat for *Megalagrion xanthomelas* but only if sufficient freshwater inflow is present (Tango 2010, p. 11). In brackish waters, naiads are likely osmoregulators that either maintain or regulate their internal fluids within a narrow range even when salinity fluctuates (Tango 2010, p. 11). However, if the salinity exceeds the osmoregulating ability of *M. xanthomelas* (>15 ppt), the naiad may experience lethal or sub-lethal stress such as changes in growth, development, or feeding (Tango 2010, pp. 11–12, p. 32). *Megalagrion xanthomelas* has also been found to tolerate water temperatures ranging from 17.5 to 31 °C but prefers temperatures ranging from 20–28 °C, and with pH's ranging from 6.5 to 9.5 (Polhemus and Asquith 1996, p. 92; Johnson 2001, p. 45; Haines 2020a, in litt.). While

M. xanthomelas appears to tolerate the presence of carp and apple snails, it does not do well in habitats containing guppies or top minnows (Polhemus and Asquith 1996, p. 92).

In the period after emergence but before reaching reproductive maturity (~20 days), it is generally unknown where adult damselflies (particularly females) go when they are not near their breeding habitats (stream, riparian vegetation) (Haines 2020b, in litt.). The relative rarity of females compared to males during surveys suggests that females spend most of their time away from aquatic habitats (perhaps as much as several hundred meters) in surrounding riparian forest habitat (Haines 2020b, in litt.). Corbet (1999, pp. 271–272) noted that other tropical damselfly species utilize multiple forest habitats, such as canopy and crowns of forest trees, strata close to the forest floor, and forest margins, but the distance from water varies by species (Haines 2020b, in litt.). While a related species, *Megalagrion blackburni*, has been documented as much as 0.25 miles (mi; 0.4 kilometer [km]) away from their breeding habitat, surveys and monitoring of *M. xanthomelas* populations suggest that they do not move great distances away from their breeding habitat. While we still do not know the extent to which *M. xanthomelas* uses the surrounding riparian vegetation, the surrounding habitat likely provides a necessary post-emergence, pre-breeding refugium for this species (Polhemus 2020a, in litt.).

Diet

In the orangeblack Hawaiian damselfly appear to be generalists at all stages (Haines 2020c, in litt.). As in most species of Hawaiian damselflies, the immature larval stages (naiads) are aquatic, breathing through three flattened abdominal gills, and are predacious (Williams 1936, p. 303). *Megalagrion xanthomelas* naiads are passive predators with exceptional vision, stalking live prey that swim or crawl within reach (Evenhuis et al. 1995, p. 18). Early stage naiads consume small zooplankton such as cladocerans, copepods, and ostracods while late stage naiads consume larger zooplankton and a variety of aquatic invertebrates (Haines 2020c, in litt.). Typical adult damselflies form a basket with their spiny legs to capture prey while flying or will perch and pounce on prey (Polhemus and Asquith 1996, p. 7). *Megalagrion xanthomelas* has been observed eating fruit flies, mosquitos, crane flies, small moths, leafhoppers, plant bugs, and sometimes other species of damselflies (Haines 2020c, in litt.). The orangeblack Hawaiian damselfly has also been observed feeding on conspecifics, however, this does not appear to be a common occurrence (Haines 2020c, in litt.).

Reproduction

Over their lifetime, male and female *Megalagrion xanthomelas* mate with multiple partners. When male *M. xanthomelas* are sexually mature, they fly to a stream and establish a territory, usually with light gaps along the stream corridor containing resting sites (Johnson 2001, p. 7). Males are territorial and guard areas of habitat where the female lays eggs (Moore 1983, p. 89). During copulation, and often while the female lays eggs, the male grasps the female behind the head with terminal abdominal appendages to guard the female against rival males; thus males and females are frequently seen flying in tandem. After mating, the male continues to grasp the female with his abdomen and will remain with her until the eggs are laid to prevent other males from mating with the female (Haines 2020c, in litt.). The eggs (typically several hundred) are deposited in the tissues of aquatic plants such as honohono grass (*Commelina diffusa*), white shrimp plant (*Justica betonica*), ivy gourd (*Coccinia grandis*), ‘ae‘ae (*Bacopa monnieri*), and lily pads through an incision cut in the vegetation (Polhemus and Asquith 1996, p. 91; Johnson

2001, p. 41; Haines 2019, in litt.). After the eggs are laid, the male and female separate and the female will usually fly away from the stream (Haines 2020c, in litt.). It takes a few more days for additional eggs to mature, at which point, the female is ready to mate again with a new male (or may use stored sperm from the previous encounter to fertilize a new batch of eggs) (Haines 2020c, in litt.). Eggs hatch after a 21-day incubation period and the developing naiad undergoes 11–17 instar stages, lasting 103–111 days, before emerging as tenerals (Johnson 2001, p. 8). Naiads of *Megalagrion xanthomelas* also behave similarly to *Megalagrion pacificum*, as these larvae tend to swim to the surface when disturbed (Englund 1999, p. 232). At the time of adult emergence, tenerals (newly emerged adults) are approximately 0.7–0.8 in (18–20 mm) in size. After they emerge, both male and female *M. xanthomelas* fly away from the stream and move to adjoining terrestrial habitats where they prey on small flying insects (Johnson 2001, p. 7). Adults have been documented to fly around for about 20 days before they are reproductively mature (Haines 2020a, in litt.).

Population Needs

We define *Megalagrion xanthomelas* populations based on their geographical distance from one another on an island. Population growth requires a sufficient number of individuals in relatively close proximity in a habitat free of threats. The orangeblack Hawaiian damselfly is considered a weak flyer, thus limiting its dispersal and connectivity potential (Jordan et al. 2007, p. 254). This trait may contribute negatively to its proficiency to find a mate especially with low population numbers. The ability of the population to expand within an occupied site is constrained by the availability and quality of suitable habitat that provides adequate food and reproductive resources.

Resiliency is the capacity of an individual or population to withstand stochastic disturbance events. The survival rate of *Megalagrion xanthomelas* offspring, population demographics, and growth rate needed to sustain a population in the presence of threats are unknown. Additionally, as noted above, accurate population estimates are difficult to determine. Thus, we base resiliency of *M. xanthomelas* mainly on habitat quality and secondarily on what we do know of population size (abundance). For *M. xanthomelas* to be abundant, it must reproduce. This requires mating at least once and having a stable to positive population growth rate. A key habitat quality that supports reproduction and population growth of *M. xanthomelas* is the availability of healthy wetlands and lowland stream habitats. This is where damselflies lay their eggs and juveniles undergo development during which they are vulnerable to environmental disturbance and predation. Another key habitat quality that supports individual survival is a healthy population of insect prey both in the water for naiad development and flying insects to meet adult needs. Resiliency also depends on the absence of threats. The greatest threat to this damselfly is the destruction of wetland and stream habitats from introduced species and anthropogenic development. In addition, *M. xanthomelas* are also vulnerable to introduced predators. Accordingly, a resilient population of *M. xanthomelas* has abundant individuals, stable to increasing populations in the wild, and access to quality habitat without threats.

Species Needs

Redundancy is the ability of *Megalagrion xanthomelas* to withstand catastrophic events and it is measured by the number of populations (redundancy/duplication), distribution of the populations across the landscape, and connectivity among population units. In order to achieve redundancy, the distribution of *M. xanthomelas* populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilience of the populations. Essentially, the more populations of *M. xanthomelas* and the broader the distribution of those populations, the more redundancy the species will exhibit thereby increasing its ability to survive a catastrophic event. Captive populations of a species may provide a source of individuals that could supplement redundancy. Currently *M. xanthomelas* collected from the one Oʻahu population are in captivity. For *M. xanthomelas*, redundancy requires the presence of multiple, stable to increasing populations distributed across its wetland and stream range on the islands of Hawaiʻi, Maui and Molokaʻi, Oʻahu, Lanaʻi, and Kauaʻi.

Representation is the ability of *Megalagrion xanthomelas* to adapt to changing environmental conditions over time and can be measured by having one or more populations of a species occupying the full range of suitable habitat used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity, within and among, populations. This allows the species to adapt to changing environmental conditions over time. While there are no historic population estimates, qualitative accounts of *M. xanthomelas* indicate that they were abundant on all of the main Hawaiian islands except for Kahoʻolawe. We have no pre-contact genetic information and thus, cannot determine how much genetic variation has been lost since humans arrived in Hawaiʻi. The mobility of *M. xanthomelas* provides a means of connecting populations to support genetic exchange and representation. However, connectivity is determined by the distance that can be reasonably achieved by the damselfly and since *M. xanthomelas* have been characterized as weak, slow fliers, population units would need to be in close geographic proximity to each other in order for genetic exchange to be likely. Thus, representation is conferred to this species by having abundant individuals in stable to increasing populations dispersed throughout its full wetland and lowland stream range on the across the Hawaiian islands that embodies the existing full genetic diversity.

FACTORS INFLUENCING VIABILITY

Threats

Habitat destruction

General – Although there has never been a comprehensive, site-by-site assessment of wetland loss in Hawaiʻi, Erikson and Puttock (2006, p. 40) estimated that at least 12 percent of all lowland to upper-elevation wetlands in Hawaiʻi had been converted to non-wetland habitat by the 1980s. Habitat loss resulted from and continues to be caused by: agricultural and urban development; stream diversion, channelization, and improper well placement; anchialine pool destruction through development; introduced feral pigs (*Sus scrofa*); introduced plants; and hurricanes, landslides, and drought. The ongoing and likely increasing effects of global climate change, while currently unquantifiable, are also likely to directly or indirectly impact the habitat of the orangeblack Hawaiian damselfly.

Stream habitat destruction – Stream modifications began with the early Hawaiians who diverted water to irrigate taro. However, early diversions often took no more than half the stream flow, and typically were periodic, to occasionally flood taro ponds year round, rather than continuously flood them (Handy and Handy 1972, pp. 58–59). The advent of plantation sugarcane cultivation led to far more extensive diversions (Wilcox 1996, p. 54). These systems were designed to tap water at upper elevations (above 984 ft; 300 m) by means of a concrete weir in the stream (Wilcox 1996, p. 54). All of most of the low or average flow of the stream was, and often still is, diverted into fields or reservoirs, leaving many stream channels completely dry (Takasaki et al. 1969, pp. 27–28; Wilcox 1996, p. 56). By 1978, the stream flow in over half of the 366 perennial streams in Hawaiʻi had been altered in some manner (Brasher 2003, p. 1055). This type of dewatering threatens the orangeblack Hawaiian damselfly species since reproduction and early life history stages occur within these lentic habitats. In addition to the destruction or diversion of most stream habitats in Hawaiʻi, the channelization of streams creates artificial, wide-bottomed streambeds and often results in the removal of riparian vegetation, which serves as habitat and potential breeding areas for *M. xanthomelas* (Brasher 2003, p. 1052). These ongoing and extensive stream diversions continue to degrade the quality of orangeblack Hawaiian damselfly habitat and its capability to support viable populations of this species.

Wetland habitat destruction – Agriculture and urban development have caused the loss of at least 30 percent of Hawaiʻi's coastal plain wetlands and 80 to 90 percent of lowland freshwater habitat in Hawaiʻi (Kosaka 1990, in litt.).

Anchialine pool habitat destruction – It is estimated that >90 percent of anchialine habitats across the state of Hawaiʻi have been historically and contemporarily lost or degraded by anthropogenic activities like coastal development and the spread of exotic species (Brock 2004, p. i). On the island of Hawaiʻi, much development occurred in the major areas for anchialine pools between Kawaiahae and Kailua-Kona which resulted in the infilling of many anchialine pools (Mitchell et al. 2005, pp. 3–19, 4–1). For example, during the construction of the Waikoloa Resort in 1985, at least 130 pools were destroyed (Brock et al. 1987, p. 201). While similar destruction is extremely unlikely to be allowed by present day regulatory agencies, given the scarcity of the anchialine pools, habitat destruction remains a potential threat (Brock and Kam 1997, p. 11). Besides the direct destruction of anchialine pools during development, more indirect but persistent effects can occur including nutrient loading and reduction in water quality. The addition of fertilizers, pesticides, and other runoff from resort, urban, and commercial development may leach into the groundwater and into anchialine pools. For example, anchialine pools at both Waikoloa and Hokuliʻa had nutrient concentrations that were >70 percent higher than concentrations reported for anchialine pools in undeveloped locations (Wiegner et al. 2006, p. 4). Moreover, it is estimated that nutrient concentrations have more than doubled since the resort's development (Cox et al. 1969, p. 2). The runoff that may leach into the groundwater may directly introduce effluents that can directly harm naiads of *Megalagrion xanthomelas* or it can also alter the chemical properties of the anchialine pool, thereby affecting productivity and all the flora and fauna that depend on that environment.

Habitat destruction by feral ungulates and invasive plants – Another major threat to *Megalagrion xanthomelas* is the ongoing destruction and degradation of wetland and lowland stream habitat by nonnative animals, particularly feral pigs (Polhemus and Asquith 1996, p. 22; Erickson and Puttock 2006, p. 42). Animals such as pigs, goats (*Capra hircus*), axis deer (*Axis axis*), black-tailed deer (*Odocoileus hemionus*), and cattle (*Bos taurus*) were introduced either by the early Hawaiians around 400 A.D. or more recently by European settlers for food and/or commercial ranching activities (Tomich 1986, pp. 120–121). In particular, pigs threaten the existence of *M. xanthomelas* by trampling the forest floor, thereby encouraging the establishment of nonnative plants, and by removing vegetation by wallowing in moist depressions (Stone 1985, p. 263; Cuddihy and Stone 1990, p. 65). In nitrogen-pool soils, feral pig excrement increases nutrient availability, enhancing establishment of nonnative weeds that are more adapted to richer soils than are native plants (Cuddihy and Stone 1990, p. 65). Rooting by feral pigs was observed to be related to the search for earthworms, with rooting depths averaging 8 in (20 centimeters; cm), and rooting was found to greatly disrupt the leaf litter and topsoil layers, and contribute to erosion and changes in ground topography (Diong 1982, pp. 150, 160–167). In addition, Mountainspring (1986, p. 98) surmised that rooting by pigs depresses insect populations that rely on ground litter for reproduction; this could impact prey availability for the damselflies (Foote 2008, in litt.; Polhemus 2008, p. 48). Feral pigs are often managed as game animals for public hunting (The Nature Conservancy 2014, p. 12). In contrast to a total eradication program, this action makes it more likely that feral pigs will continue to exist in Hawaiʻi, and thus likely that pigs will continue to destroy and degrade habitat of *M. xanthomelas*.

The invasion of nonnative plants primarily contributes to habitat destruction and modification by: 1) adversely impacting microhabitats by modifying the availability of light; 2) altering soil-water regimes, 3) modifying nutrient cycling processes; and 4) outcompeting native plant species (Cuddihy and Stone 1990, p. 74). For example, the invasive nonnative California grass (*Urochloa/Brachiaria mutica*), forms dense stands that can completely eliminate open water and thus continues to alter the habitat of *Megalagrion xanthomelas* through conversion of marshlands to meadowlands (Mazzacano 2007, p. 2). Other invasive plants that threaten habitat suitable to *M. xanthomelas* include pickleweed (*Salicornia* sp.) and mangrove (*Rhizophora mangle*); mangroves create dark, dense-canopied swamp habitats that are not favored by *M. xanthomelas* (Polhemus and Haines 2020, p. 7).

Anthropogenic habitat destruction – Until 1995, the island of Lānaʻi hosted the second largest set of *Megalagrion xanthomelas* populations (Polhemus et al. 2020, p. 20). A number of these populations were within or near the former golf course at Kōʻele. However, massive reconfigurations of the water features have caused extensive disturbance to the habitat of *M. xanthomelas* and therefore no longer support any populations. Additionally, the stocking of invasive fish (see effects below) have made these habitats additionally unsuitable for the persistence of this species.

Invasive species

Predation by nonnative animal species poses a significant threat to the orangeblack Hawaiian damselfly throughout its current and historical range for the reasons that follow.

Nonnative fish – The absence of Hawaiian damselflies, including *Megalagrion xanthomelas,* in many streams and other aquatic habitats around the Hawaiian islands is strongly correlated with the presence of predatory nonnative fish as documented in numerous observations and reports (Englund 1999, p. 237; Englund 2004, p. 27; Englund et al. 2007, p. 215). In fact, the introduction of non-native fish has been implicated in the extirpation of a related damselfly, the Pacific Hawaiian damselfly (*M. pacificum*), from Oʻahu, Kauaʻi, and Lānaʻi (USFWS 2014, p. 5). Naiads of *M. xanthomelas* are particularly vulnerable to predation from nonnative fish, especially species within the Poeciliidae family, as they feed and rest near the surface of the water (USFWS 2010, p. 35992). Hawaiian damselflies evolved with very few, if any, predatory fish and the exposed behavior of most of the fully aquatic species, such as *M. xanthomelas*, makes them particularly vulnerable to predation by nonnative fish which can be very aggressive (USFWS 2014, p. 5). For example, when disturbed, naiads of *M. xanthomelas* tend to swim to the surface; however, this appears to be a completely ineffective response against the surface-oriented poeciliid predators (Englund 1999, p. 232). Thus, the orangeblack Hawaiian damselfly is no longer found in most lentic habitats in Hawaiʻi, such as ponds and taro (*Colocasia esculenta*) fields, due to predation on larvae by nonnative fish that now occur in these systems (Moore and Gagne 1982, p. 4; Englund et al. 2007, p. 215). Over 51 species of nonnative fishes are established in freshwater habitats on the Hawaiian Islands from sea level to over 3,800 feet (1,152 meters) elevation (Staples and Cowie 2001, p. 32; Brasher 2003, p. 1054; Englund 1999, p. 226, Englund and Polhemus 2001; Englund 2004, p. 27, Englund et al. 2007, p. 232). The spread of these nonnative fishes has also been facilitated by intentional human introduction in the recent past. For example, in 2001 during a dengue fever outbreak, people intentionally introduced fish to streams on Maui in an effort to control mosquito populations (Polhemus 2008, in litt.). Since the time of human contact, over 70 species of fish have been introduced into Hawaiian freshwater habitats (USFWS 2014, p. 5). Therefore, predation by nonnative fishes is considered a significant and immediate threat to *M. xanthomelas*.

Invasive fish are particularly a problem in anchialine pools. It is estimated that more than 95 percent of anchialine pools in West Hawaiʻi have been contaminated by invasive fish and that this spread has only occurred over the past 20–30 years (Yamamoto and Tagawa 2000, entire; Havird et al. 2013, pp. 189–190). The effects of invasive fish on the damselfly naiads are unknown but may include direct competition and predation to indirect, e.g. the introduction and transmission of parasites and disease (Maciolek and Brock 1974, entire). Some alien species include members of the Poeciliidae (e.g. mosquito fish (*Gamubusia affinis*), shortfin or Atlantic molly (*Poecilia mexicana*), and guppy (*Poecilia reticulata*)) and the tilapia (*Tilapia mossambica*). Tilapia (family Cichlidae) were brought to Hawaiʻi for aquaculture. *Gambusia affinis* was introduced to the island as a biological control agent in 1905 and has since spread throughout Hawaiʻi (Dudley et al. 2017, p. 2). While invasive fishes remain the main threat, other native fishes commonly found offshore such as āholehole (*Kuhilia* spp.) or ulua/pāpio (*Caranx* sp.) may also pose a threat if introduced into the anchialine pool system.

Backswimmers – Backswimmers are aquatic insects in the family Notonectidae, which are nonnative to Hawaiʻi. Several species (*Anisops kuroiwae*, *Buenoa pallipes*, and *Notonecta indica*) are established on the islands of Maui, Hawaiʻi, Lānaʻi, and Oʻahu (USFWS 2016, p. 67818). These insects prey on damselfly naiads in streams and other aquatic habitat, and are considered a threat to the orangeblack Hawaiian damselfly since this species has an aquatic naiad life stage. In addition, the presence of backswimmers inhibits the foraging behavior of damselfly naiads, with negative consequences for growth, development, and survival (USFWS 2010, p. 36002). Backswimmers are reported on all of the main Hawaiian islands, except Kahoʻolawe.

Other insects – *Megalagrion xanthomelas* frequently co-occurs with a number of non-native insects that may pose a threat to their continued existence. For example, it was initially thought that there was no evidence of adverse interactions between *M. xanthomelas* and the non-native damselflies *Ischnura ramburi*, *Ischnura posita*, and *Enallagma civile* (Polhemus and Asquith 1996, p. 92). However, Daigle (2000, p. 4) reported seeing these two introduced species preying on teneral adult *M. xanthomelas* at thet Ninole Springs, Hawaiʻi population site. Another insect group that may pose a threat to *M. xanthomelas* are the nonnative insect group, Trichoptera (or caddisflies) (USFWS 2014, p. 7). While it cannot be confirmed due to a lack of research on the subject, it is suspected that the introduced caddisflies may adversely affect *M. xanthomelas* through competition for space and resources (USFWS 2014, p. 7).

Coqui frogs – Coqui frogs, *Eleutherodactylus coqui*, were introduced to the State of Hawaiʻi in the late 1980s (Woolbright et al. 2006, p. 122) and are widespread on the island of Hawaiʻi (HDLNR 2020). They are also known to be in a few locations on Maui, Kauaʻi, and Oʻahu (HDLNR 2020). On Maui, populations of frogs are known in and around nurseries and hotels, residential areas, and there are several large populations in natural areas (Maui Invasive Species Committee 2018, entire). Although there have been significant efforts to control the coqui frogs on Maui (O'Neill 2018, in litt.) the frogs have limited predators (mongoose, rats, and feral cats) enabling them to become successful invaders across wet forest habitats and allowing their populations to grow extraordinarily dense in Hawaiʻi compared to in their native habitat of Puerto Rico (Woolbright et al. 2006, pp. 124–126). The spread in natural areas poses a threat to *Megalagrion xanthomelas*. While naiads are not likely affected by the coqui frog as these frogs do not breed in streams or other places where *M. xanthomelas* immatures occur (O'Neill 2018, in litt.), adults may be threatened. An analysis of coqui frog diets at lowland sites on the islands of Hawaiʻi and Maui found many invertebrates consumed by the frogs were leaf litter insects. However, a large number of flying insects were also present, indicating these frogs are actively foraging while climbing trees or understory plants (Beard 2007, p. 281, 283). Dietary analysis of the coqui frog on the island of Hawaiʻi showed that aerial insects make up 33.8 percent of the diet (Bernard & Mautz 2016, p. 3413). The frogs have the ability to consume 4,500–56,000 prey/hectare/night, with 1,500–19,000 of these being aerial insects (Bernard & Mautz 2016, p. 3414). Based on the spatial patterns of the coqui frog foraging behavior, the orangeblack Hawaiian damselfly adult stages are potentially vulnerable to coqui frog predation. Further, coqui could compete with the orangeblack Hawaiian damselfly for food resources.

Bullfrogs – Nonnative bullfrogs, *Lithobates catesbeianus*, are strongly correlated with the absence of Hawaiian damselflies (Englund et al. 2007, pp. 215, 219). Bullfrogs are reported to occur on all of the main Hawaiian islands (IUCN 2015, entire). The bullfrog was first introduced into Hawaiʻi in 1899 (USFWS 2011, p. 14) to help control insects, specifically the nonnative Japanese beetle (*Popillia japonica*), a significant pest of ornamental plants (USFWS 2011, p. 14). Bullfrogs have demonstrated great success in establishing new populations wherever they have been introduced (Moyle 1973, p. 19) and are flexible in both habitat and food requirements (Bury and Wheland 1984, p. 11). Bullfrogs also prefer habitats with dense vegetation and relatively calm water (Bury and Whelan 1985). Because of this behavior, it is likely of particular threat to *Megalagrion pacifium* because this species also prefers calm water habitat. In addition, bullfrog tadpoles feed mainly on aquatic plants and invertebrates and thus may also be a threat to *M. xanthomelas*.

Ants – Nonnative, predatory ant species pose a threat to both naiads and adults of *Megalagrion xanthomelas*. Naiads are vulnerable to predation in their terrestrial or semi-terrestrial habitats, or when emerging from the water for metamorphosis. In a 1998 survey of an Oʻahu stream, researchers observed predation by ants upon*M. xanthomelas* (USFWS 2010, p. 36001). The range of the orangeblack Hawaiian damselfly overlaps with that of several particularly aggressive, nonnative, predatory ant species. Notable predatory species that pose a direct threat include the big headed ant (*Pheidole megalocephala*), yellow crazy ant (*Anoplolepis gracilipes*), Argentine ant (*Linepithema humile*), and the thief ant (*Solenopsis papuana)* that currently occur on all of the main Hawaiian islands (Reimer 1993, pp. 11–22; Bertelsmeier et al 2015, pp. 2491–2503; Krushelnycky et al 2017, pp. 254–259). The threat is amplified by the fact that many of these species have winged reproductive adults (Borror et al. 1989, p. 738) and can quickly establish new colonies in suitable habitats (Staples and Cowie 2001, p. 55). While ants generally prefer drier habitat sites, some species of ants (e.g. the yellow crazy ant and thief ant) have increased their range into riparian areas. Based on observations by Dr. David Foote of the U.S. Geological Survey (Foote 2008, in litt.), yellow crazy ants may threaten populations of *M. xanthomelas* in mesic areas up to 2,000 ft (600m) in elevation. In addition, an unknown number of new species of ants are established every few years (Staples and Cowie 2001, pp. 55–57). These attributes allow some ants to destroy otherwise geographically isolated populations of native arthropods like *M. xanthomelas* (Nafus 1993, pp. 19, 22–23).

Birds – At Tripler Army Medical Center (TAMC), red-vented bulbuls (*Pycnonotus cafer*) and red-whiskered bulbuls (*Pycnonotus jocosus*) were observed foraging along the stream and catching insects (Preston and Arakaki 2012, p. 4). On a single occasion, a red-whiskered bulbul was observed catching and eating a newly emerged *M. xanthomelas* adult (Preston and Arakaki 2012, p. 4) In another observance, staff at Lyon Arborteum on Oʻahu observed a bulbul catch a teneral damselfly as it flew away from the pond shortly after emergence (Haines 2019, in litt.). At this time it is unknown exactly what impact bulbuls may have on *M. xanthomelas*, but from these two observances it appears that bulbuls exert pressure on teneral damselflies and once they mature and harden, the damselflies may be able to evade bird predation relatively well.

Other predators – In laboratory tests, Johnson (2001, p. 66) found that the crayfish *Procambarus clarkii* ate *Megalagrion xanthomelas* naiads in 71 percent of the feeding tests conducted. Actual predation of naiads in the wild have not been documented as of yet. Another potential predator of *M. xanthomelas* adult is the Jackson's chameleon, *Trioceros jacksonii* (USFWS 2016, p. 67818).

Inadequacy of existing regulatory mechanisms

Inadequate Habitat Protection: Nonnative feral ungulates pose a threat to *Megalagrion xanthomelas* through destruction and degradation of the species' habitat, but regulatory mechanisms are inadequate to address this threat (USFWS 2016, pp. 67824, 67844–67847). The State of Hawaiʻi provides game mammal (feral pigs and goats, axis deer, and mouflon sheep) hunting opportunities on 10 State-designated public hunting units on the island of Hawaiʻi (HDLNR 2003, pp. 10–11 and 62–65); 7 units for Maui (HDLNR 2003, p. 57); 5 units for Molokaʻi (HDLNR 2003, p. 52); 7 units for Oʻahu (HDLNR 2003, p. 47); 11 units for Kauai (HDLNR 2003, p. 8). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas to removal by State staff, or their designees, in other areas (State of Hawaiʻi, H.A.R. 13-123). In addition, the State Water Code has the regulatory mechanism in place to protect *M. xanthomelas* or their habitat, but water regulations have not been followed or enforced in a consistent manner by the State's Water Commission to prevent degradation of habitat. The State of Hawaiʻi considers all natural flowing surface water (streams springs, and seeps) as State property (Hawaiʻi Revised Statues 174c 1987) and the Hawaiʻi Department of Land and Natural Resources (HDLNR) has management responsibility for the aquatic organisms in these waters (Hawaiʻi Revised Statutes Annotated, 1988, Title 12:1992 Cumulative Supplement). However, administration of the Clean Water Act permitting program by the U.S. Army Corps of Engineers has not provided substantive protection of damselfly habitat, including any requirements for retention of adequate instream flows. This dewatering may threaten the orangeblack Hawaiian damselfly species as they are dependent on streams and seeps. State and Federal regulatory mechanisms are not adequately controlling the spread of nonnative animal species between islands and watersheds. Predation by nonnative animal species poses a major ongoing threat to *M. xanthomelas*. Because existing regulatory mechanisms are inadequate to maintain aquatic habitat for the damselflies and to regulate the spread of nonnative species, the inadequacy of existing regulatory mechanisms is considered to be a significant and immediate threat.

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawaiʻi (USFWS 2016, pp. 67824, 67844–67847). The Hawaiʻi Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawaiʻi, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations (USFWS 2016, pp. 67824, 67844–67847). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities. (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq*.), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawaiʻi allows the importation of most plant taxa, with limited exceptions (USFWS 2016, pp. 67824, 67844–67847). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawaiʻi have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2016, pp. 67824, 67844–67847).

Biological Limitations

While exact population numbers are unknown, most populations of *Megalagrion xanthomelas* are thought to be relatively small in size. As a result of low known numbers, *M. xanthomelas* may experience the following: reduced reproductive success due to inbreeding depression, reduced levels of genetic variability leading to diminished capacity to respond and adapt to environmental changes, and increased vulnerability to localized catastrophes such as hurricanes, tsunami, and drought. Together these may result in population extirpation and extinction of this species.

Although there are a number of populations of *Megalagrion xanthomelas* the persistence of *M. xanthomelas* is threatened by having several small geographically isolated populations across three islands. This leaves the species vulnerable to local extirpation events and extinction from natural and anthropogenic caused factors. The demographic structure needed to support *M. xanthomelas* is unknown. Small isolated populations may be particularly vulnerable to reduced mating encounters and decreased reproductive success caused by inbreeding depression. These populations may suffer a loss of genetic diversity over time due to random genetic drift, resulting in a decreased evolutionary potential and lessened ability to cope with environmental change (Lande 1988, p. 1455).

Environmental Factors

Stochastic (random, naturally occurring) events such as hurricanes, landslides, and drought, can alter or degrade the habitat of *Megalagrion xanthomelas* directly by modifying and destroying native riparian, wetland, and stream habitats (e.g. rocks and debris falling in a stream; mechanical damage to riparian and wetland vegetation), and indirectly by creating disturbed areas conducive to invasion by nonnative plants that outcompete the native plants used by damselflies for perching. Data on precipitation in Hawaiʻi shows a steady and significant decline of about 15 percent over the last 15–20 years (Diaz et al. 2005, p. 2; Chu and Chen 2005, pp. 4803–4805; Hiromasa-Browning 2019, p. 227). These stochastic events like droughts and storms may also cause temporary habitat loss (e.g. desiccation of streams, die-off of surrounding vegetation). For example, the last natural population of *M. xanthomelas* on Oʻahu was nearly eliminated during a flood and was recolonized from a remnant population occurring in mitigation ponds that were built upslope of the flooded area (Mazzacano 2007, p. 2). Similarly, on Molokai, a re-survey in 1995 of an area known to host widespread *M. xanthomelas* revealed that *M. xanthomelas* was now only found in a small area along the seaward margin of the stream (Polhemus and Haines 2020, p. 16). The cause of this decline was attributed to a major flood that scoured the area, allowing large stands of non-native plants such as Job's tears (*Coix lachrymal-jobi*) and Guinea grass (*Panicum maximum*) to overtake the wetland area making it unsuitable for *M. xanthomelas* (Polhemus and Haines 2020, p. 16). A further resurvey of this area resulted in no sightings of *M. xanthomelas* (Polhemus and Haines 2020, p. 17). Floods have also been implicated in dramatically reducing numbers of *M. xanthomelas* in Olowalu Valley on Maui (Bustamente 2020, in litt.).

Catastrophic events such as hurricanes, landslides, tsunamis, and volcanic eruptions represent a significant threat to native riparian, wetland, and stream habitats. These types of events are known to cause significant habitat damage and could result in local extirpation events. For example, *Megalagrion vagabundum*, a related damselfly species, was extirpated from the entire Hanakāpīʻai Stream system on Kauaʻi as a result of the impacts from Hurricane Iniki in 1992 (USFWS 2012, p. 57673). Tsunamis also pose a threat since *Megalagrion xanthomelas* typically inhabits low-lying wetland areas. Finally, although no formal survey has been conducted, the population of *M. xanthomelas* that used to occupy Green Lake (Wai-a-Pele) near Kapoho is presumed extirpated as during the eruption of Kīlauea in 2018, lava flows entered the lake thereby evaporating the water and completely filling the basin (Peterkin 2018, entire).

While the exact nature of the impacts of climate change on native Hawaiian ecosystems are unknown, they will likely include the loss of aquatic habitat through reduced stream flow, the evaporation of standing water, flooding of nearshore wetlands, and the loss of native riparian plants that comprise the habitat in which *Megalagrion xanthomelas* occurs (USFWS 2010, p. 36000). Future changes in precipitation and the forecast of those changes are highly uncertain because they depend in part, on how the El Niño-La Niña weather cycle might change (Hawaiʻi Climate Change Action Plan 1998, pp. 2–10). Although sea level rise is expected to increase the total amount of Hawaiʻi's wetlands through groundwater inundation as well as marine flooding and inundation (Hiromasa-Browning 2019, p. 226), significant changes in water chemistry due to increased flooding and inundation during storms and high tides are also expected (Hiromasa-Browning 2019, p. 226). These changes in water chemistry are likely to limit the types of flora and fauna that are able to live in this new system. In addition, sea level rise is likely to impact the availability of anchialine pool habitat availability. While current geospatial models show new pools are likely to form inland due to sea level rise and that the high subsurface hydrologic connectivity can allow for these new habitats to be used for breeding by *M. xanthomelas* (Oki 1999, pp. 1–70; Kano and Kase 2004, pp. 423–424; Craft et al. 2008, pp. 676–677), higher water levels and more frequent storm surges may allow introduced fishes to disperse into new areas which predate upon naiads (Marrack 2015, entire).

Conservation Actions

Endangered Species Act

The Service in 2016 determined endangered status under the Endangered Species Act of 1973 (Act), as amended, for 49 plants and animals from the Hawaiian Islands including *Megalagrion xanthomelas* (USFWS 2016, entire). The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Conservation measures provided to species listed as endangered or threatened under the Act include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The Act and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the Act prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the Service and State conservation agencies. The Service may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Damaging or destroying any of the listed plants in addition is violation of the Hawaiʻi State law prohibiting the take of listed species. The State of Hawai'i's endangered species law (HRS, Section 195-D) is automatically invoked when a species is Federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. *Megalagrion xanthomelas* occurs on both Federal and non-Federal lands.

Restoration of Water

One of the greatest threats to *Megalagrion xanthomelas* is historical habitat destruction such as the channelization, de-watering, and diversion of streams for agricultural purposes. However, with the collapse of some large-scale agricultural industries like sugarcane, the idea of restoring diverted waters back to natural stream flows has made a resurgence. For example, in June 2018, the State of Hawaiʻi Commission on Water Resource Management ordered the full restoration of flows to 10 streams on Maui and ordered no or limited diversions, for seven streams in the east Maui watershed (HDLNR 2018, entire). The Commission's decision will return free flowing water, with no upstream diversions, to the following streams: Hanehoi, Honopū, Huelo, Kualani, Makapipi, ʻOhiʻa (Waianui), Palauhulu, Piʻinaʻau, Wailuanui, and Waiokamilo. The majority of these 10 streams have been diverted for over 100 years. The Commission's decision also orders East Wailua Iki, Honomanū, Kopiliula, Waikamoi, Punalau/Kōlea, Waiohue, and West Wailua Iki streams to have limited or no water diversions, in order to foster improved habitat for native fish and other stream animals. The two exceptions are Waiohue and West Wailua Iki streams, which are to remain un-diverted so that total flow is restored as habitat reference streams and important estuaries.

Removal of Non-native Plants and Animals

One of the primary threats to the orangeblack Hawaiian damselfly is the loss of habitat from invasive plants and animals. On Maui, efforts have been made by the State of Hawaiʻi Department of Land and Natural Resources Division of Forestry and Wildlife (DOFAW) to clear invasive plants that crowd and overshade streams and ponds, thereby making the habitat more suitable for *Megalagrion xanthomelas* (Bustamente 2020, in litt.). There have also been concerted efforts ongoing over the past several years to resolve State regulatory and permitting issues to allow for the removal of nonnative fish and the restoration of stream habitat. In addition, the State of Hawaiʻi's Aquatic Invasive Species (AIS) program works to control, manage, and prevent introduced aquatic pests (HDLNR 2020, entire). Work from this program includes various methods of non-native fish removal including dewatering, netting and trapping, electrofishing, and other biocontrol methods (Tavares 2009, p. 2). However, once an invasive fish has become established, especially in remote stream areas, they can be difficult to eradicate (HDLNR 2003, entire).

Translocation and Captive Rearing

The Service, in partnership with DOFAW, University of Hawai‘i, the Bishop Museum, and the O‘ahu Army Natural Resources Program (OANRP) have been working on re-establishing populations of *Megalagrion xanthomelas* on O‘ahu through translocations and a captive rearing program. While naiads were being raised in the lab from eggs collected in the wild since 2018, a captive population was started in late 2019 after an unknown pathogen caused severe mortality in eggs recently collected from the Tripler Army Medical Center (TAMC) - the last remaining wild population on O‘ahu. However, even in this short amount of time, the captive rearing of *M. xanthomelas* has yielded a tremendous amount of information on the damselfly’s life history including, development, diet, fecundity, and life span (Haines 2020a, in litt.). Haines (2020a, in litt.) also stated that these captive rearing methods could be applied to other *Megalagrion* species.

Within the last 25 years, conservation efforts have included site suitability testing and more recently, translocation releases in the Dillingham Military Reservation (June 2020–present), Waianae Kai Forest Reserve (January–February 2019, March 2019, September 2019), Lyon Arboretum (April–May 2019), and at a site adjacent to TAMC (Haines 2020a, in litt.). As of early August 2020, 1008 individuals have been released at Dillingham and 420 individuals at TAMC (Haines 2020d, in litt.). Conservation efforts at TAMC for *Megalagrion xanthomelas* have been ongoing since 1995. Once thought extirpated on O‘ahu, in 1994, a very small population was discovered in pools of an intermittent stream at the TAMC (Englund 2001, p. 256). The Service has cooperated with the Office of Veterans Affairs and the U.S. Army to protect the last remaining population on O‘ahu. Mitigation measures, including the building of mitigation ponds, were successful in preventing the extirpation of the population during a construction project. Fortunately, these mitigation ponds housed a reserve population of *M. xanthomelas* since a severe flood in 1995 wiped out the entire stream population. Although these ponds were dismantled in 2000, the damselflies still exist in a stream near TAMC. The stream is now artificially fed water thorough a pipe maintained by the U.S. Army (Ogden Environmental and Energy Service 1994). The TAMC site has been extensively monitored since 1997, almost weekly at times, and in 2012 the population size was estimated to range from a low of 50 to a high of 1056 with an average of 395 individuals (Preston and Arakaki 2012, p. 6; Preston and Arakaki 2013, p. 14).

Although no introduced populations on O‘ahu are established and self-sustaining, all sites are carefully monitored (Haines 2020a, in litt.; Polhemus 2020b, in litt.). Haines (2020a, in litt.) stated that the most significant challenge has been identifying appropriate translocation sites that not only have the desired abiotic and biotic characteristics (low elevation, slow moving streams or ponds that lack invasive fish and other predators), but that are also located in areas where the species would not be in conflict with human-mediated activities. Some other challenges to establishing a successful translocated population have included predators such as non-native fish and invertebrates, severe storms, and environmental conditions that are not conducive for early life history stages (e.g. water temperature, salinity) (Englund 2001, p. 261; HDLNR 2014, in litt.). As such, even sites that initially appeared favorable have proved unsuitable. However, new sites, including neighbor islands, are constantly being evaluated for future releases.

CURRENT CONDITION

Historic Condition

Pre-human Habitat and Species Distribution

The Hawaiian damselflies in the genus *Megalagrion* are endemic, and found only in Hawaiʻi. All species of *Megalagrion* appear to have evolved from a single ancestor, which naturally colonized the Hawaiian archipelago. Although their exact history is unclear, these damselflies may have been in Hawaiʻi for more than 5.1 million years (age of Kauaʻi, the oldest main Hawaiian island) (Polhemus and Asquith 1996, p. 9). The *Megalagrion* damselflies are one of the few diversified groups of Hawaiian aquatic insects that are derived from freshwater ancestors, and probably colonized the Hawaiian islands by aerial dispersal (Polhemus and Asquith 1996, p. 9). However, this trait has likely been lost since *Megalagrion* damselflies are more sedentary and interisland dispersal is rare (Polhemus and Asquith 1996, p. 9). Although no species of *Megalagrion* have gone extinct since humans arrived on the islands, there have been alarming declines and local extirpations of these native Hawaiian damselflies in the past few decades (Polhemus and Asquith 1996, p. 21).

Historic trends

Historic wetland distribution

Before the modern era, estimates of the total prehuman extent of wetland habitat across the state of Hawaiʻi ranged from 20,963 hectares (ha; 209.63 square kilometers; km^2) to 126,300 ha (1263 square kilometers; km^2) (Hiromasa-Browning et al. 2019, p. 218). Although there has never been a comprehensive, site-by-site assessment of wetland loss in Hawaiʻi (Erikson and Puttock 2006, p. 40; Dahl 1990, p. 7) it is estimated that 31 percent of coastal wetland area has been lost since prehuman times (Kosaka 1990, in litt.; van Rees and Reed 2014, pp. 345–348; Hiromasa-Browning 2019, p. 221) and at least 12 percent of all wetlands, including lowland to upper-elevation wetlands, had been converted to non-wetland habitat by the 1980s. Around 800 AD Polynesians first colonized the Hawaiian islands (Vitousek et al. 2004, p. 1665) and altered wetlands for agriculture and fishing. Despite these modifications, many areas of extensive wetlands remained intact and were still utilized by the native fauna (USFWS 2011, p. 7). Many low-to-mid elevation freshwater wetlands were used for the agricultural production of kalo or taro. In fact, by 1778 kalo was cultivated in nearly every valley in the main Hawaiian islands that contained a stream (Kirch 1982, p. 3). As such, it has been proposed that Polynesians actually increased the extent of the wetland ecotype in the islands (Stone, 1989 in Hiromasa-Browning 2019, p. 219). However, after the arrival of Westerners in 1778 a series of events including the beginning of sugarcane cultivation, led to extensive stream diversions and dewatering which dramatically altered the current extent of wetland habitat. By the early 1900s, most lowland wetlands were filled or otherwise modified (USFWS 2010, p. 35996).

Historic stream distribution

Prior to the arrival of Polynesians approximately 1500 years ago, streams in the Hawaiian archipelago likely looked much different than they do today (Valeros et al. 2020, p. 384). However, no references or descriptions are available for this prehuman time period. Historically, stream habitat diversity depended upon sufficient mountain elevation to generate orographic rainfall (Valeros et al. 2020, p. 386). In general, stream habitats exhibit high representation on islands with higher elevations, with more diversity on windward sides of the islands (Valeros et al. 2020, p. 386).

Historic anchialine pool distribution

Anchialine pools are defined as a body of water often with mixed salinity within a geological formation (coastal lava flows or limestone exposures) that exposes the underlying water table, and are tidally influenced (Hiromasa-Browning et al. 2019, p. 4). These pools include typical small bodies of water as well as water in lava fields, tubes, cracks, and under rock overhangs, and open wells, and may occur singly or in groups (Maciolek and Brock 1974, pp. 2–6). Pools display tidal dampening with some pools only having water at high tide. These pools have subterranean connections to the groundwater and ocean but have no regular surface connection to the sea (Holthuis 1973, p. 3; Sakihara 2012, pp. 83–84). Water chemistry is highly variable with salinities ranging from zero to 41 parts per thousand (ppt) and surface temperatures ranging from 17 to 36 °C (Yamamoto et al. 2015, entire; Hiromasa-Browning 2019, p. 4). Hawai‘i is the only state in the United States with anchialine pools and the Hawaiian name for an anchialine pool is Wai ‘opāe - wai means water and ‘opāe means shrimp (HDLNR, n.d.; Hui Aloha Kiholo, 2020). However, there is very little information on the pre-human distribution of anchialine pools in Hawai‘i. Since anchialine pools are dependent on underground movement and flow of water and thus require porous volcanic or limestone substrates, it is possible that anchialine pools were present wherever this type of rock formation occurred in close proximity to the ocean. In Hawai‘i, the volcanic basalt parent material and derived minerals are extremely porous, and ancient limestone coral uplifts or karst material are full of cracks and crevices allowing water to drain to a water table, deep below the surface (Maciolek 1969, entire).

Historic species distribution

Little is known about the historical abundance, population trends, and demographic features of the orangeblack Hawaiian damselfly. This species used to be Hawai‘i’s most abundant species of damselfly and it utilized a variety of aquatic habitats for breeding sites (USFWS 2014, p. 3). Historically, *Megalagrion xanthomelas* were found in the wetlands and lowland streams of all of the main Hawaiian islands except Kaho‘olawe at low elevations below 200 feet (61 meters) (Polhemus and Asquith 1996, p. 92) (Table 1). Specimen records are present for Ni‘ihau, O‘ahu, Moloka‘i, Lāna‘i, Maui, and Hawai‘i; also recorded in the literature from Kaua‘i (Figure 2). Although no documented specimens of *M. xanthomelas* have actually been collected on Kaua‘i, based on the historical distribution across all of the main Hawaiian islands including the closest islands of O‘ahu and Ni‘ihau, the species was likely present (Figure 2), it is almost certain that the species once occurred on Kaua‘i (Polhemus 2020b, in litt.). It is likely that widespread alteration of lowland aquatic ecosystems on Kaua‘i occurred early enough in the post-contact period that species were extirpated before it could be scientifically collected (Polhemus 2020b, in litt.). This species was historically common and abundant in a variety of lowland habitats through the 1970s, after which populations declined (Mazzacano 2007, p. 2).

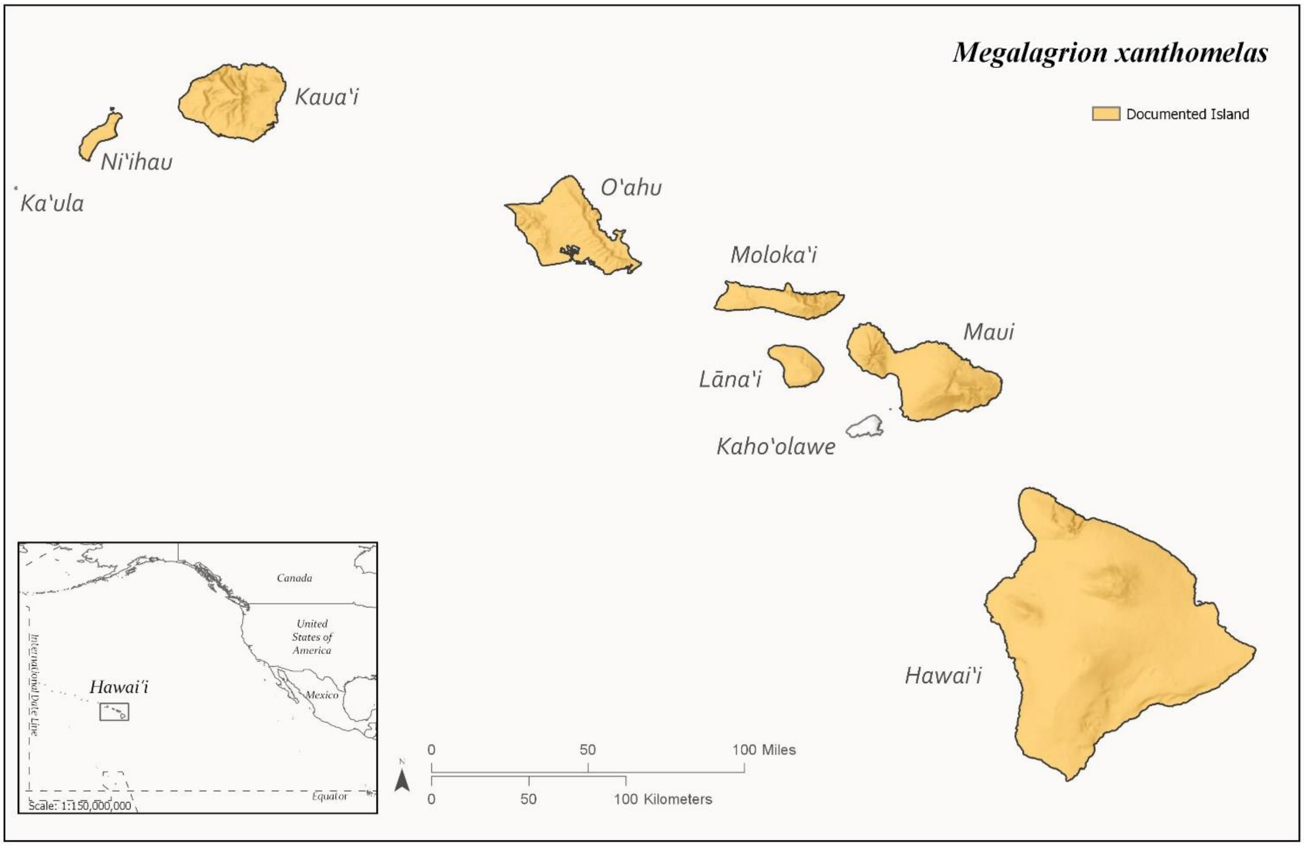


Figure 2. Islands historically occupied by the orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*.

Table 1. Historical sites of *Megalagrion xanthomelas* where this species is now presumed to be extirpated.

HISTORIC (EXTIRPATED) SITES:				
Island	**Location**	**Elevation**	**Last Survey**	**Last Observed**
Hawaiʻi	Kapoho*	10 ft (3 m)	1995	1995
	Naʻalehu	800 ft (244 m)	unknown	1975
	Panaʻewa	380 ft (116 ft)	unknown	1968
Maui	West Maui Mountains	unknown	unknown	1975
	Kanaio	unknown	2000s	1998
	La Perouse	unknown	2000s	1998
Lānaʻi	Lōpā	5 ft (1.5 ft)	2020	1994
	Haua	unknown	unknown	1994
	Keōmuku	10 ft (3 m)	2020	1994
	Paliamano- Kōʻele Lodge	1600 ft (488 m)	2020	1993
	Maunalei Gulch	10-350 ft (3-107 m)	2020	1994
Molokaʻi	Kainalu Stream	10 ft (3 m)	2020	1927
	Kaunakakai Gulch	unknown	unknown	1970
	Mapulehu Gulch	500 ft (152 ft)	unknown	1947
	Pelekunu Valley (part of)	10 ft (3 m)	2020	1995
Oʻahu	Koko Head	480 ft (146 m)	unknown	1926
	Mānoa	1000 ft (305 m)	unknown	1900
	Waialua	10 ft (3 m)	unknown	1892
	Waiʻanae Mountains	2000 ft (610 m)	unknown	1892
	Waimano	200 ft (61 m)	unknown	1977
Kauaʻi	Unknown	unknown	unknown	unknown
Niʻihau	Unknown	unknown	unknown	1947

*The population near Kapoho in Green Lake (Wai a Pele) is presumed extirpated since the lava flow from the 2018 eruption of Kīlauea volcano in lower Puna boiled all the water away and completely filled the basin.

Current Condition

Current wetland distribution

The last comprehensive wetland inventory for all of the islands in the State of Hawaiʻi was completed in 1979 by the Service (Cowardin et al. 1979, entire). To this day, there is no completely accurate map available for Hawaiʻi's wetlands although various attempts have been made. Kosaka (1990, in litt.) and van Rees and Reed (2014, pp. 345–348) have made estimates to determine the amount of wetland and open water bodies that have been lost from pre-Polynesian contact and the mid-1990s. These studies indicate that approximately 31 percent of coastal wetland has been lost across Hawaiʻi; the highest wetland loss has occurred in the lowland wetland subtypes (at or below approximately 300 m elevation) with majority of it occurring on Oʻahu (Kosaka 1990, in litt.; van Rees and Reed 2014, pp. 345–348; Hiromasa-Browning 2020, p. 221).

Current stream distribution
Although no formal estimate has been made of stream loss since prehuman contact, stream habitats in Hawaiʻi continue to be threatened by diversion, channelization, and withdrawals of stream water for agricultural, industrial, and individual use or flood control (Valeros et al. 2020, p. 386). For examples, one-fifth of Hawaiʻi's streams, mostly on Oʻahu, have been either channelized or straightened in order to carry floodwaters away from people and property, stabilize stream banks, or increase the amount of land for development (Valeros et al. 2019, p. 8). Other continual threats include runoff and development associated with agricultural and urban practices, invasive species, and climate change (Valeros et al. 2020, p. 386).

Current anchialine pool distribution
Anchialine pools exist on Oʻahu, Molokaʻi, Kahoʻolawe, Maui, and the island of Hawaiʻi. It is estimated that >90 percent of anchialine habitats across the state of Hawaiʻi have been historically and contemporarily lost or degraded by anthropogenic activities like coastal development and the spread of exotic species (Brock 2004, p. i). There are currently an estimated 700 anchialine pools found throughout the Hawaiian islands, although they are most abundant on the islands of Hawaiʻi and Maui (Hiromasa-Browning 2020, p. 9). In fact, over 650 of the 700 recorded pools are located on the island of Hawaiʻi (Brock 2004, p. i).

Current species distribution
The orangeblack Hawaiian damselfly was once Hawaiʻi's most abundant damselfly species, found on all of the main Hawaiian islands except Kahoʻolawe. (USFWS 2016, p. 67817). Although there are no quantitative population estimates for this species, *Megalagrion xanthomelas* is now only found on the islands of Hawaiʻi, Maui, Molokaʻi and Oʻahu (Table 2). *Megalagrion xanthomelas* is now considered extirpated from Kauaʻi (Polhemus and Asquith 1996, p. 91) and Lānaʻi (Polhemus and Haines 2020, entire). The status of the population on Niʻihau is unknown. Populations on Molokaʻi and Hawaiʻi are considered locally abundant. The three populations on Maui are still extant but not abundant. Until recently, the last report of the orangeblack Hawaiian damselfly on Oʻahu was in 1935 (Williams 1936, p. 310), and it was believed extirpated on this island (Polhemus 1993, pp. 344, 346). In 1994, a very small population was discovered existing in pools of an intermittent stream at the TAMC (Englund 2001, p. 256). Aside from translocated populations set out by DOFAW, *M. xanthomelas* at TMAC is still the only known naturally occurring population remaining on Oʻahu.

As detailed above, the Service in partnership with DOFAW, University of Hawaiʻi, the Bishop Museum, and U.S. Army's Natural Resources Program have been working on re-establishing populations of *Megalagrion xanthomelas* on Oʻahu through translocations and a captive propagation program. Within the last 25 years, conservation efforts have included site suitability testing and more recently, translocation releases in the Dillingham Military Reservation, Waiʻanae Kai Forest Reserve, Lyon Arboretum, and at a site adjacent to the remaining wild population at TAMC (Table 2). Each of these sites have been carefully monitored. The population at TAMC has been extensively monitored, almost weekly at times, and in 2012 the estimated population size is thought to range from a low of 50 to a high of 1056 with an average of 395 individuals (Preston and Arakaki 2012, p. 6; Preston and Arakaki 2013, p. 14). Some challenges to establishing a successful translocated population have included predators such as non-native fish in adjacent streams or ponds creating population sinks, storms, and environmental conditions that are not conducive for early life history stages (HDLNR 2014, in litt.).

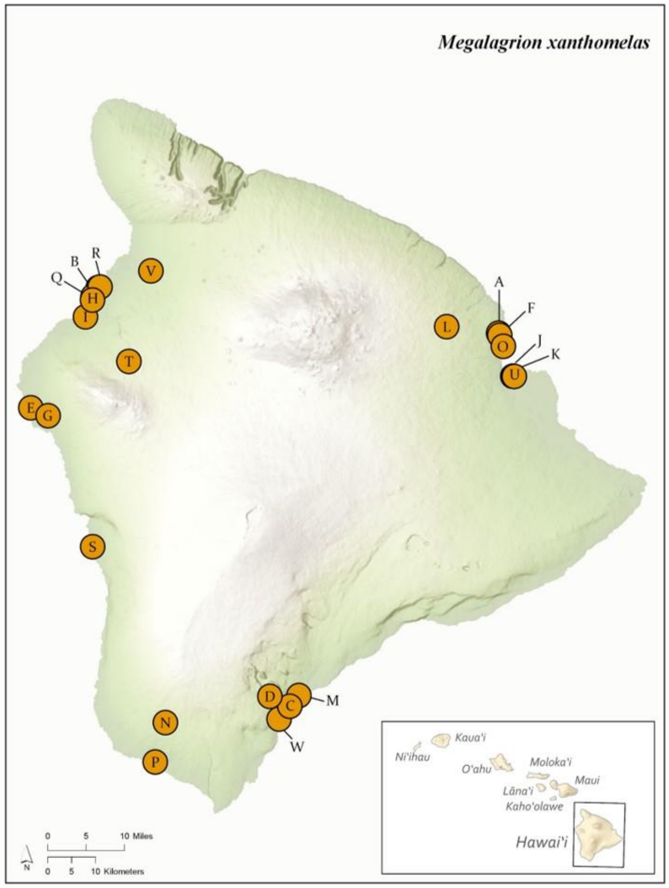
Two recent surveys of Molokaʻi (Polhemus and Haines 2020, entire) and Lānaʻi (Polhemus et al. 2020, entire) offer extensive insights into the populations on both islands. In a 2020 re-survey of four sites on Molokaʻi known to host *Megalagrion xanthomelas*, this species was still found in most historical sites (Polhemus and Haines 2020, p. 18). No *M. xanthomelas* were found at the original site at Kainalu Stream, which is now channelized and fenced but adjacent wetlands on private property may still present suitable habitat (Polhemus and Haines 2020, p. 8). The other Molokaʻi site from which *M. xanthomelas* was reported in the 1990s, but not seen during the current surveys was the Pahiomu Fishpond, on the leeward coast (Polhemus and Haines 2020, p. 18). Since the last survey in 1995, the Pahiomu Fishpond has become overgrown and shaded by mangroves, which is not preferred by *M. xanthomelas* (Polhemus and Haines 2020, p. 9). One of the historical sites on Molokaʻi that still supported *M. xanthomelas* was at Kapuāiwa coconut grove (Polhemus and Haines 2020, p. 5) where a robust population was observed. The basal springs within this area have been protected from significant biological disturbance, such that the spring heads and outflows are still free from introduced fishes (Polhemus and Haines 2020, p. 6). Another site where *M. xanthomelas* was still found was in the Palaʻau wetland complex. Although there are introduced topminnows (*Gambusia* sp.) that occupy the least saline pools in this complex, *M. xanthomelas* still persists in the area, perhaps taking advantage of escape space from topminnows due to its greater salt-tolerance (Polhemus and Haines 2020, p. 7). Polhemus and Haines (2020, p. 20) also noted that the population at Palaʻau appears to offer a potential source of breeding individuals that may be used to reintroduce to Lānaʻi, where it has been recently extirpated (Polhemus et al. 2020, entire), because they are haplotypically similar (Jordan et al. 2005, p. 3460). The open marshy areas on the flat valley floors of Pelekunu Valley appear to support moderately abundant populations of *M. xanthomelas*; here, they were found flying together with *Megalagrion pacificum* and perching on emergent vegetation amid pig wallows (Polhemus and Haines 2020, p. 15). In observing populations of *M. pacificum* and *M. xanthomelas* in Pelekunu valley, Polhemus and Haines (2020, p. 17) noted that the habitats exploited by *M. xanthomelas* may be seasonal in more dynamic aquatic systems. In dry summer months, when the old taro fields dry out and large scouring floods are infrequent, *M. xanthomelas* may breed in the terminal pond and seepage-fed side channels along the lower course of the main stream channel (Polhemus and Haines 2020, p. 17). However, during the winter, when the old taro fields become partially flooded and marsh-like, *M. xanthomelas* appears to move back into this area, possibly to avoid impacts from high impact stream flooding (Polhemus and Haines 2020, p. 17). It is also possible that individuals seen along the stream channel during the summer months are spillover from the larger core breeding populations in the old taro fields that persist throughout the year (Polhemus and Haines 2020, p. 17). Overall, Polhemus and Haines (2020, p. 18) noted that Molokaʻi has always had a much more limited human population in comparison to nearby islands such as Oʻahu and Maui and they conclude that this relatively limited development on Molokaʻi has as a consequence preserved populations of lowland *Megalagrion* damselflies that are now very rare or extirpated on other islands (Polhemus and Haines 2020, p. 18).

Recent survey work on Lana‘i demonstrated that all populations of *Megalagrion xanthomelas* present on that island in the 1990s are now apparently extirpated (Polhemus et al. 2020, entire). Up until 1995, Lāna‘i harbored what was probably the second-largest set of populations for this endangered species outside of the island of Hawai‘i. In the 1995 survey, *M. xanthomelas* was found occupying a small wetland area on the floor of the Maunalei Gulch Canyon (Polhemus et al. 2020, p. 6). But examination of this same area in 2020 showed that all aquatic habitat has disappeared because the pipeline that used to feed the wetland is now broken, discontinuous, and inoperative (Polhemus et al. 2020, p. 6). Another area in the upper reaches of Maunalei Gulch was observed to contain suitable habitat for *M. xanthomelas* if the poeciliid fishes were eliminated (Polhemus et al. 2020, p. 7). *Megalagrion xanthomelas* was also found in Keōmuku town in 1994, but 2020 surveys found no sign of the species and no suitable habitat as former freshwater inflows have now been taken over by mangroves (Polhemus et al. 2020, p. 12). *M. xanthomelas* also used to be present in multiple ornamental features on the Experience at Kō‘ele golf course, which was detailed by Polhemus (1996, pp. 37–38). Since the mid-1990s, the main pond at the old Lodge at Kō‘ele, pond at the former 18th hole, former 8th hole, and former 4th hole, where *M. xanthomelas* was previously observed has been drained, reconfigured and stocked with topminnows; consequently, there are no damselflies present (Polhemus et al. 2020, p. 16). Other areas such as ponds at the former 16th and 17th hole have not been extensively modified but topminnows have been introduced which prevent the persistence of *M. xanthomelas* (Polhemus et al. 2020, p. 17).

Table 2. Currently known populations of *Megalagrion xanthomelas*.

CURRENT SITES:					
Pop Unit	**Island**	**Location**	**Elevation**	**Last Observed**	**Number of individuals observed***
A	Hawaiʻi	Alakaʻi Stream	180ft (55m)	1995	+
B	Hawaiʻi	ʻAnaehoʻomalu Bay	10ft (3m)	1994	1
C	Hawaiʻi	Hīlea	unknown	1994	1
D	Hawaiʻi	Kaʻalāiki	unknown	1994	3
E	Hawaiʻi	Kaloko-Honokōhau National Historical Park	5ft (1.5m)	2019	+
F	Hawaiʻi	Kawainui Stream	160ft (49m)	1995	+
G	Hawaiʻi	Kealakehe	unknown	1994	1
H	Hawaiʻi	Keawaiki	20ft (6m)	1990s	+
I	Hawaiʻi	Kīholo Bay	10ft (3m)	1994	1
J	Hawaiʻi	Leleiwi	5ft (1.5m)	1995	+
K	Hawaiʻi	Liliʻuokalani	5ft (1.5m)	1995	+
L	Hawaiʻi	Makahanaloa	unknown	1995	+
M	Hawaiʻi	Nīnole	10ft (3m)	1994	+
N	Hawaiʻi	Oceanview	unknown	1990	+
O	Hawaiʻi	Pāpaʻikou	10ft (3m)	1994	2
P	Hawaiʻi	Pōhue Bay	10ft (3m)	1990s	+
Q	Hawaiʻi	Pueo Bay	20ft (6m)	1990s	+
R	Hawaiʻi	Puu Anahulu	unknown	1990	+
S	Hawaiʻi	Puʻuhonua	unknown	2008	+
T	Hawaiʻi	Puʻu Waʻawaʻa	unknown	1994	1
U	Hawaiʻi	Waiākea	unknown	1995	+
V	Hawaiʻi	Waikōloa	unknown	1994	+
W	Hawaiʻi	Whittington Beach Park	10ft (3m)	1994	2
X	Maui	Nānuʻalele Point	unknown	2020	+
Y	Maui	Olowalu Valley	unknown	2020	+
Z	Maui	Ukumehame	400ft (122m)	1997	+
AA	Molokaʻi	Kapuāiwa Coconut Grove	3ft (1m)	2020	+
AB	Molokaʻi	Kauhakō Lake	unknown	2006	+
AC	Molokaʻi	Meyer Lake	2021ft (616m)	1970	+
AD	Molokaʻi	Pālāʻau Wetland Complex	10-30ft (3-9m)	2020	+
AE	Molokaʻi	Pāpiʻo Gulch	unknown	1996	+
AF	Molokaʻi	Pelekunu Valley	0-65ft (0-20m)	2020	+
AG	Molokaʻi	Waikolu Valley	10ft (3m)	1995	+
AH	Oʻahu	Tripler/Moanalua[†]	200ft (61m)	2020	+

* + indicates that no abundance data was available but at least one damselfly was recorded.
[†]Tripler/Moanalua includes both naturally occurring *Megalagrion xanthomelas* and translocated individuals



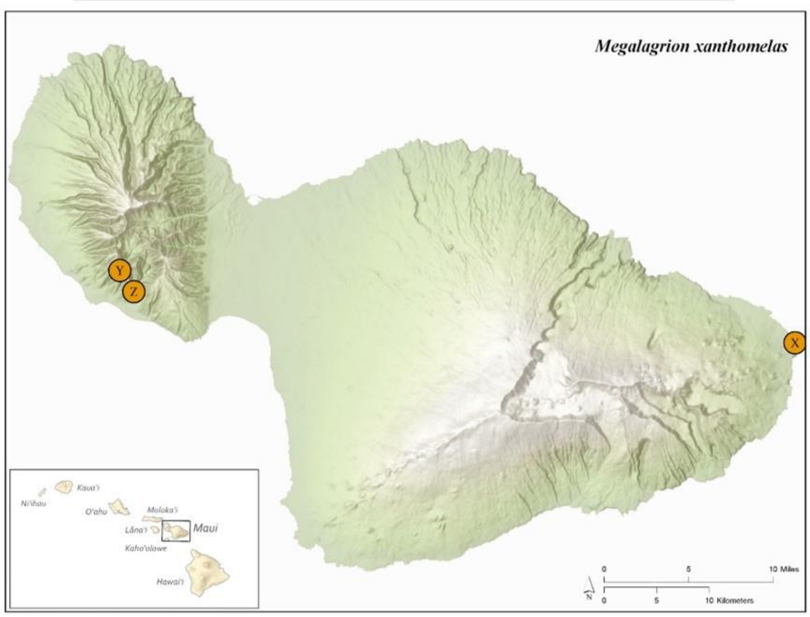


Figure 3. Current distribution (population units A-AH) of the orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*, on the islands of Hawai‘i, Maui, Moloka‘i, and O‘ahu.

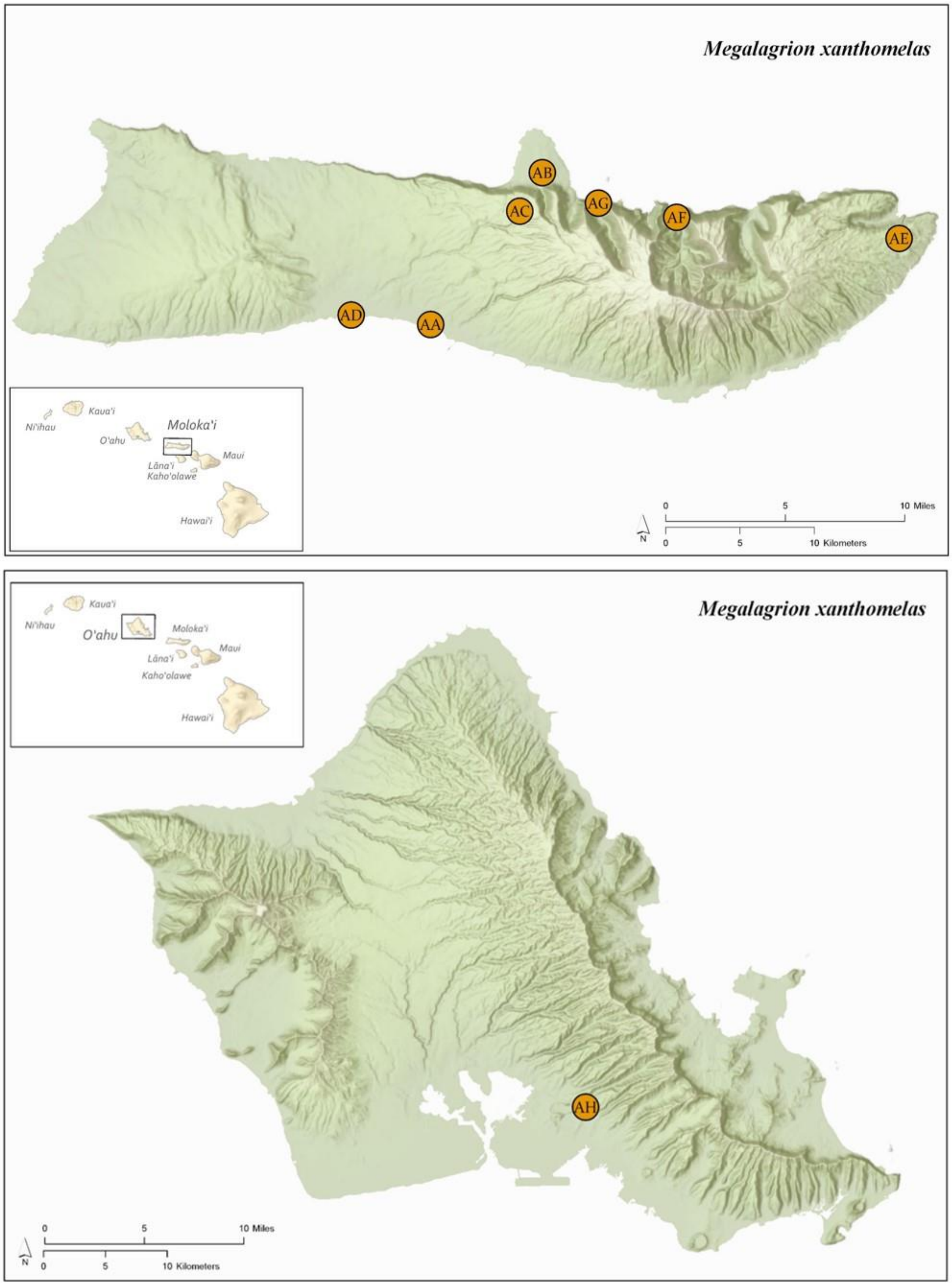


Figure 3. Current distribution (population units A-AH) of the orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*, on the islands of Hawai‘i, Maui, Moloka‘i, and O‘ahu—Continued.

SPECIES VIABILITY SUMMARY

Resiliency

Resiliency is the capacity of an individual or population to withstand stochastic disturbance events. We define resiliency for *Megalagrion xanthomelas* based on population size, population growth rate, and habitat quality. However, there are very few estimates of population size for *M. xanthomelas*. As noted previously, population estimates for damselflies can be difficult because damselflies often occupy remote or difficult to access locations and they have tendency to hide during cold, windy, or rainy days. In addition, while male *M. xanthomelas* are brightly colored and are more inclined to fly when approached, females tend to perch low in the vegetation (Preston 2007, p. 272).

The orangeblack Hawaiian damselfly was once Hawaiʻi's most abundant damselfly species, historically found on all the Hawaiian islands except for Kahoʻolawe. Now, *Megalagrion xanthomelas* is found only on Oʻahu, Maui, Molokaʻi, and Hawaiʻi. This suggests a moderate but severely reduced level of resiliency compared to its historic distribution. *Megalagrion xanthomelas* inhabits wetlands, streams, and anchialine pools (USFWS 2016, p. 67817). The orangeblack damselfly has even been found exploiting and thriving in a number of artificial habitats (e.g. TAMC, Kōʻele). This ability to exploit different types of habitats gives *M. xanthomelas* a high level of resiliency. However, most if not all of these habitats have also experienced a high rate of disturbance and loss since pre-human contact. Although there has not been a formal assessment of either the wetland or stream habitat in Hawaiʻi, it is estimated that at approximately 31 percent of coastal wetland has been lost since prehuman contact (Kosaka 1990, in litt.; van Rees and Reed 2014, pp. 345–348; Hiromasa-Browning 2020, p. 221) and one-fifth of Hawaiʻi's streams have been channelized or straightened for anthropogenic purposes (Valeros et al. 2020, p. 386). Similarly, over 90 percent of anchialine pools across the state have been destroyed (Brock 2004, p. i). This level of habitat loss suggests a very low level of resiliency.

Climate change also continues to pose a threat. Events such as droughts and severe flooding events are predicted to increase in frequency and intensity (Hawaiʻi Climate Change Action Plan 1998, pp. 2–10). Such events are likely to cause habitat destruction and may result in the local extirpation of certain populations, as has occurred previously on Oʻahu and Molokaʻi. Increases in the frequency and intensity of storm surges may also pose a challenge for *Megalagrion xanthomelas* living in anchialine pools. *Megalagrion xanthomelas* are particularly sensitive to increased salinity and may become extirpated from pool habitats if salinities rise beyond 15 ppt (Tango 2010, p. 32). Storm surge may alter the salinity balance in these pools. Although events such as severe flooding may be localized, *M. xanthomelas* are considered relatively weak flyers and do not stray far from their breeding grounds. Therefore, simply moving to another part of an island is not a viable option.

Conservation efforts such as the restoration of flow to an altered stream may be beneficial to *Megalagrion xanthomelas*. For example, flow restoration to a stream at TAMC led to an increased abundance of *M. xanthomelas*; after 10 months of flow restoration, adult damselfly observations increased from 17 to 162 adults per monitoring period (Englund 2005, p. 136). However, water management in Hawaiʻi remains a complicated issue. Additionally, while stream flow may provide more available physical habitat, invasive plants and animals continue to threaten the quality of that habitat. Feral ungulates and invasive plants also continue to threaten the existence of *M. xanthomelas* by destroying vegetative habitat that is essential for hunting, breeding, and rearing. However, the presence of non-native aquatic predators such as fish present some of the greatest threats to the persistence of *M. xanthomelas*. The lack of *M. xanthomelas* in many aquatic habitats around the Hawaiian islands is strongly correlated with the presence of predatory nonnative fish. In addition, development and anthropogenic disturbances have proven to be devastating to populations on Lānaʻi. In 1995, *M. xanthomelas* was highly abundant on multiple locations on Lānaʻi and hosted the second-largest set of populations for this species outside of the island of Hawaiʻi; in 2020, a re-survey of the island found *M. xanthomelas* to be completely extirpated from Lānaʻi primarily because of habitat destruction (Polhemus et al. 2020, entire). Reintroduction into these sites are also not possible due to the nearly ubiquitous presence of poeciliid topminnows (Polhemus et al. 2020, p. 20) Based on the severe restriction of its range due to habitat modification/destruction, water management practices, drought, feral ungulates, and nonnative predators, the resiliency of *M. xanthomelas* is very low.

The remaining populations on Oʻahu, Maui, Molokaʻi, and Hawaiʻi Island are small in size, suggesting a low level of resiliency. Because observed abundances are so low and observations often depend on the environmental conditions or the season of the survey it is difficult to estimate if any of these populations are increasing, decreasing, or stable. For example, Hawaiian damselflies can be difficult to spot because they tend to perch in low thick vegetation and often hide during rainy or windy weather. However, based on years of observations of various populations across the state, Polhemus (2020, in litt.) concluded that the species is gradually being reduced to a set of progressively smaller and more isolated metapopulations. Small sized populations are extremely vulnerable to reduced reproductive success caused by inbreeding depression and loss of genetic variation over time due to random genetic drift, which results in a decreased evolutionary potential and ability to cope with environmental change (Lande 1988, p. 1455). Small populations like these are also demographically vulnerable to extinction caused by random fluctuations in population size and sex ratio (Lande 1988, p. 1455). For example, a reduction in availability of breeding habitat or increases in predation of naiads may result in a significant decrease in survivorship or reproduction, which might not have long-term effects on large populations but could increase the chance of extirpation for relatively small, isolated populations. Thus, their long-term persistence is largely reduced and the small population size of *Megalagrion xanthomelas* magnifies the severity of the impacts from the threats discussed above.

Based on these findings, we determine that resiliency of the orangeblack Hawaiian damselfly, *Megalagrion xanthomelas*, is <u>low</u> for the following reasons:

(+) for increased resiliency, (-) for reduced resiliency

1) Still found on multiple islands (+) but this range is severely reduced in comparison to historical distribution (-).

2) *M. xanthomelas* has the ability to exploit a number of habitats including artificial habitats (+) but most of these habitats have and continue to experience severe degradation (-).
3) *M. xanthomelas* on Lānaʻi have been completely extirpated due to habitat destruction and ongoing anthropogenic disturbance (-).
4) Highly sensitive to de-watering events brought on by natural causes such as drought or anthropogenic causes such as channelization or diversion (-).
5) Restoration of stream flow may increase habitat availability (+) but water management in Hawaiʻi is complicated (-).
6) Invasive plants and animals pose a severe threat through predation and habitat destruction (-).
7) Observed occurrences of individuals in each population are limited which leads to biological limitations with small population size (-).

Megalagrion xanthomelas has <u>low</u> resiliency.

Redundancy

Redundancy is the ability of *Megalagrion xanthomelas* to withstand catastrophic events and is measured by the presence of multiple, stable to increasing populations distributed across its full habitat range on Oʻahu, Maui, Molokaʻi, and Hawaiʻi. There are currently thirty-four known naturally occurring population units across four islands (1 on Oʻahu, 3 on Maui, 7 on Molokaʻi, and 23 on Hawaiʻi). With the exception of the single population on Oʻahu, the presence of multiple populations on three other islands suggests a moderate to high level of redundancy. While there are multiple populations within relatively close distance to one another (e.g. Hawaiʻi, Maui, Molokaʻi) these damselflies are also known to be weak flyers, which means that there is a low probability of connectivity and dispersal. Even within an island, there is likely very limited connectivity between populations. On the island of Hawaiʻi there are clusters on the west, east, and south shores of the island which may be connected (Figure 3); but these clusters are also at a higher risk of complete extirpation by a single catastrophic event. Because *M. xanthomelas* do not disperse widely, chances of re-populating these areas after a catastrophic event are slim. In addition, dispersal away from the single population would likely require either continuous habitat free of threats or aided translocation. However, the extent of suitable habitat been highly reduced, degraded, and fragmented, since prehuman contact and these habitats continue to be threatened by anthropogenic use and invasive species (Erikson and Puttock 2006, p. 40; Dahl 1990, p. 7; Valeros et al. 2020, p. 386). Even though *M. xanthomelas* is able to exploit artificial habitats, they are still vulnerable to immediate extirpation. For example, many of the populations on Lānaʻi depended upon artificial habitat (e.g. golf course ponds) but recent construction and re-development of these areas has led to local extirpation events to the point where *M. xanthomelas* is considered completely extirpated from the island of Lānaʻi. The fragmented and highly degraded nature of the available habitat means there is a low amount of potential habitat available for *M. xanthomelas* and low potential for population expansion. Therefore, we conclude that the functional redundancy of *M. xanthomelas* is low to moderate. Although there are multiple populations on three of the four populated islands, the low dispersal ability of *M. xanthomelas* and the presence of the majority of populations to restricted geographic locations on each island (e.g. east Maui, northeast Moloka‘i) makes this species vulnerable to catastrophic events such as hurricanes and landslides. Any of these events could easily result in the local extirpation of the species.

However, conservation efforts on O‘ahu including captive breeding and rearing efforts greatly increase the redundancy of *Megalagrion xanthomelas*. While the captive breeding and rearing efforts are relatively new, efforts related to translocations around the islands of O‘ahu have been ongoing for about 25 years. Initial site selection experiments dominated the early years of the translocation efforts, but recent translocations have shown initial promising results and conversations of attempting translocations on neighbor islands are ongoing. Although the current translocated individuals on O‘ahu have not yet become self-sustaining populations these sites are constantly monitored. The continued progress of these conservation efforts may greatly increase the redundancy of this damselfly species. Thus, based on these findings, we determine that redundancy of the orangeblack Hawaiian damselfly is <u>moderate</u> for the following reasons:

(+) for increased redundancy, (-) for reduced redundancy

1) Habitat availability is highly reduced and fragmented (-).
2) Even though *M. xanthomelas* can exploit different habitats (+), immediate threats continue to persist (-).
3) There are multiple populations across four islands (+) but connectivity may be low (-). In the case of a local extirpation, re-population is not likely to occur naturally (-).
4) A single catastrophic event could result in local extirpation events (-).
5) Concerted conservation efforts including a captive population (+) and multiple translocation sites with promising results that are consistently monitored (+).

Megalagrion xanthomelas has <u>moderate</u> redundancy.

Representation

Representation is the ability of *Megalagrion xanthomelas* to persist and adapt to changing environmental conditions over time. This would require more than one stable to growing population on O‘ahu, Maui, Moloka‘i, and Hawai‘i in all suitable habitats that are free of threats. Although there are thirty-four known populations of *M. xanthomelas* across four islands, suitable habitat quality and quantity has declined significantly since pre-human contact and continues to be threatened by invasive species and other anthropogenic activities. Therefore, while there are multiple populations across multiple islands, quality habitat that is available for *M. xanthomelas* is extremely low which suggests low to moderate representation.

Although genetic diversity also contributes to a species ability to adapt to changing environments and *Megalagrion xanthomelas* is perhaps the most studied *Megalagrion* species in Hawai‘i, we still have a limited amount of genetic information on this species. However, since *M. xanthomelas* has been extirpated from almost half of the islands that it historically occupied, we can infer that a high amount of genetic diversity has already been lost. Jordan et al. (2007, p. 248) in a phylogeographic study of existing damselfly species in Hawai‘i stated that *M. xanthomelas* is an example of phylogenetically related ecological vulnerability. Phylogeographic analysis found that *M. xanthomelas* separated into three different clades, Oʻahu, Maui Nui, and the island of Hawaiʻi (Jordan et al. 2007, p. 252). This confirms that there is little to no connectivity between islands and what genetic similarities still remain may be the result of prehistoric connections.

Perhaps unsurprisingly, the last remaining naturally occurring population on Oʻahu is known to have experienced recent severe bottlenecks (Englund 2001, p. 262; Jordan et al. 2007, p. 249). This population is an extreme case of genetic inbreeding and even with a relatively high sample size (20 individuals), they all had the same mtDNA haplotype (Jordan et al. 2007, p. 257). Since *M. xanthomelas* from Molokaʻi have the same mitochondrial haplotype as the population from Oʻahu, damselflies from Molokaʻi may be used to increase genetic diversity in future conservation efforts.

The Maui Nui populations displayed a much lower mtDNA (mitochondrial DNA) diversity than populations on the island of Hawaiʻi (Jordan et al. 2005, p. 3467). This difference in genetic diversity is likely the result of severe population bottlenecks from repeated sea level fluctuations during the Pleistocene; these fluctuations may have caused the Maui Nui damselfly populations to undergo many boom and bust cycles, resulting in a lower overall effective population size and subsequent loss of haplotype diversity (Jordan et al. 2005, p. 3467). However, according to Jordan et al. (2005, p. 257), *M. xanthomelas* on Molokaʻi showed an even lower genetic diversity compared to populations on Maui, even though the *M. xanthomelas* found on Molokaʻi are considered to be the healthiest populations (high abundance) occurring in the most pristine streams in Hawaiʻi (Jordan et al. 2005, p. 257). This suggests that the long-term outlook for the populations on Molokaʻi may not be good and these populations may eventually suffer from inbreeding depression.

The haplotypes found on Hawaiʻi island are the most different from Maui Nui and Oʻahu *M. xanthomelas* populations; these haplotypes are also low in frequency and appear to be the result of limited immigration (Jordan et al. 2007, p. 254). This is not surprising, as the island of Hawaiʻi has never been connected to Maui Nui (Jordan et al. 2007, p. 254). In addition to its differentiation from the populations on other islands, Jordan et al. (2007, p. 257) also found that *M. xanthomelas* on the island of Hawaiʻi showed a great deal of genetic diversity. Jordan et al. (2007, p. 257) also mentioned that while there is not enough genetic differentiation to support species-level recognition, the *M. xanthomelas* on the island of Hawaiʻi are genetically unique and should be managed as a separate entity within the species. Therefore, amongst other considerations, while the island of Hawaiʻi contains the greatest number of populations of *M. xanthomelas*, because of this genetic differentiation they may not be able to supplement other populations on other islands.

Based on these findings, we determine that redundancy of the orangeblack Hawaiian damselfly is <u>low to moderate</u> for the following reasons:

(+) for increased representation, (-) for reduced representation

1) There are multiple populations on multiple islands (+).
2) Quality (threat-free) habitat availability is low (-).

3) The Oʻahu population has extremely low genetic diversity (-) but because *M. xanthomelas* on Molokaʻi share the same mtDNA, translocation of individuals from that location may be used to increase genetic diversity (+).
4) The genetic diversity of the Maui populations remain high (+) but those on Molokaʻi are relatively low and the long-term outlook for the species may not be good (-).
5) *M. xanthomelas* on the island of Hawaiʻi have high genetic diversity (+) but are also genetically unique and therefore may not be very useful in translocating to other islands to increase current population sizes (-).

Megalagrion xanthomelas representation is <u>low to moderate</u>.

Summary

Megalagrion xanthomelas is currently known from thirty-four populations on the islands of Oʻahu, Maui, Molokaʻi and Hawaiʻi. Resiliency of the populations is considered low to moderate because of the increasingly reduced abundance compared to historical estimates, continuing habitat destruction, and high risk of local extirpation from non-native predators. Redundancy is considered moderate because there are multiple populations on multiple islands; however, *M. xanthomelas* habitat is highly fragmented and thus catastrophic events can still result in local extirpation events. Representation for this species is considered low to moderate because genetic diversity in Oʻahu and Molokaʻi populations are extremely low. Maui and Hawaiʻi genetic diversity remain high but *M. xanthomelas* on the island of Hawaiʻi are unique and therefore may not be suitable for increasing genetic diversity in other island populations. Overall, the limited habitat and small, scattered populations of *M. xanthomelas* may affect long-term stability. However, concerted conservation efforts including captive breeding/rearing and translocations may aid greatly in this species's recovery. Therefore, the current viability of *Megalagrion xanthomelas* is low to moderate (Table 3).

Table 3. Viability summary of *Megalagrion xanthomelas*, under current conditions.

Species	Resiliency	Redundancy	Representation	Viability
Megalagrion xanthomelas	Low	Moderate	Low to moderate	Low to moderate

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